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Automatic exploration of the landscape of optical problem using the Simultaneous Multiple Surfaces method

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Abstract: An automated method was developed to explore the landscape and find different configurations for fast freeform dioptric systems in the Long-Wave Infrared band for automotive application. It uses the Simultaneous Multiple Surfaces method. © 2023 The Author(s)

1. Introduction

Since its inception, the design of optical imaging systems has relied on spherical surfaces and later on rotationally symmetric surface. However, in the '70s, the first optical system with a surface without rotational symmetry was commercialized [1]. In this paper, freeform surface refers to surfaces without rotational symmetry [2]. By bringing more degrees of freedom to the designer, freeform systems can out-compete classical systems on all requirements [3].

However, the use of freeform optics makes the optimization of the merit function more complex due to a large number of degrees of freedom. In turn, this increases the impact of the designer's experience even more than the design of classical systems.

Here we apply the direct construction method called Simultaneous Multiple Surfaces [4–6] to scan the optical merit function (MF) of an optical problem. We used the SMS-3S-3D method to obtain freeform starting point that can be further optimize with a commercial optical software.

2. Discussion

The automated method has three different steps. The first one is to compute numerous freeform systems using the SMS-3S-3D method. Doing so and varying different parameters of the initial settings of the SMS-3S-3D method allows us to find different resulting systems. The resulting systems comprise three freeform surfaces and one last plane surface. Moreover, in this study, we decided only to vary two parameters, the radii of curvatures of surfaces 1 and 2 close to the optical axis. We chose those two parameters as the study's variables as we identified them as the more impacting parameters among the initial settings' parameters.

The second step automatically optimizes systems obtained at the end of the first step in Zemax OpticStudio. To realize this automated optimization of the systems, we have defined a standard optimization function that we apply the same way for every system. This standard optimization function optimizes systems based on the centroid of the different fields, the transverse aberrations, and mechanical constraints.

The third step enables us to automatically analyze the optical quality of all the optimized systems and classify them into different configurations following a defined criterion. In this study, we use the sign of each best fit sphere (BFS) of each surface of the systems as the configuration criterion. This criterion is arbitrary and not infallible, but it allows us to identify different configurations quickly. Now that we automatically generate systems over a part of the landscape of the problem's merit function, the designer has to pick one of the systems found. To choose the best system for his problem, the designer can refer to different parameters, such as the optical quality reached, the compactness of the configuration, etc.

2.1. Results

In our study, we decided to optimize the system over a rectangular FOV since it has been shown that optimizing on the useful rectangular FOV improves the optical quality of the system furthermore [7, 8]. However, optimizing

Parameter	Value
FOV	$\pm 33.7^\circ \times \pm 26.6^\circ$
F/#	2.0
Focal length	4.8mm
VGA detector	640×480
Pixel size	$10 \mu\text{m}$
Number of freeform surface	3
Type of surface 4	plane

Table 1: Specifications of the optical problem

on a rectangular FOV imposes the use of freeform surfaces as we break the rotational symmetry of the problem. Tab. (1) resumes the specifications of the optical problem that we want to solve by scanning its MF.

We explored the landscape of the MF according to the two radii of curvatures R_1 and R_2 . We varied respectively radii between ± 100 mm and between ± 150 mm, generating 2500 combinations of initial settings. After the computation of each SMS system and its automatic optimization in Zemax we distinguished 4 configurations according to the BFS criterion. Fig. 1 shows the distribution of the configurations according to $1/R_1$ and $1/R_2$ and their layout. In that case, all the configurations have a mean RMS spot radius inferior to the radius of the Airy disk.

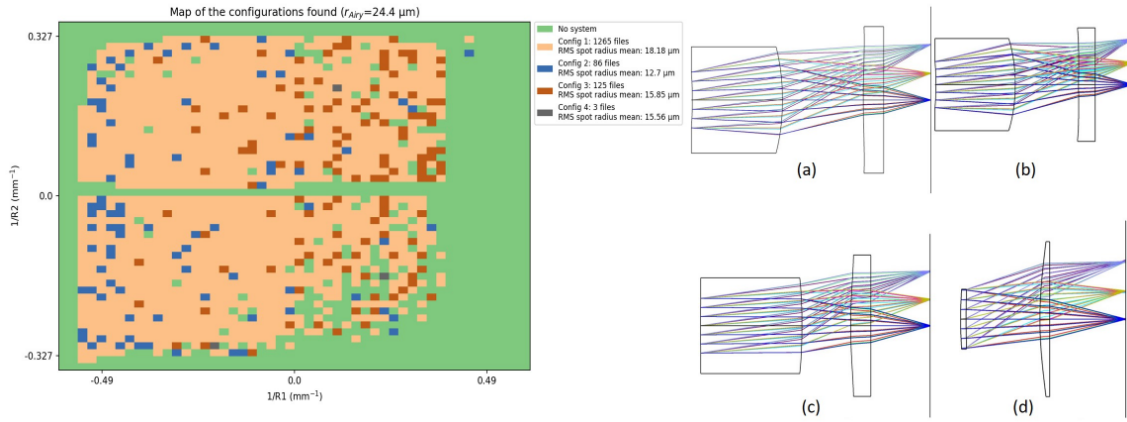


Fig. 1: Map representing the different configurations found according to $1/R_1$ and $1/R_2$ and layout of the four different configurations, (a) Configuration 1; (b) Configuration 2; (c) Configuration 3 and (d) Configuration 4

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